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IS 5921-1 (1993): Metal-clad base materials for printed circuits for use in electronic and telecommunication equipment, Part 1: General requirements and test [LITD 5: Semiconductor and Other Electronic Components and Devices]

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इलैक्ट्रॉनिकी और दूरसंचारण उपस्कर में प्रयुक्त मुद्रित सर्किट के लिए धातु से ढकी आधारभूत सामग्रियाँ

भाग 1 सामान्य अपेक्षाएँ और परीक्षण

(दूसरा पुनरीक्षण)

Indian Standard

SPECIFICATION FOR METAL-CLAD BASE MATERIALS FOR PRINTED CIRCUITS FOR USE IN ELECTRONIC AND TELECOMMUNICATION EQUIPMENT

PART 1 GENERAL REQUIREMENTS AND TEST

(Second Revision)

UDC 621-3·049·75 : 621·315·619 : 669·386·8 : 621·38·39·38

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NEW DELHI 110002

October 1993

Price Group 10

Printed Circuits Sectional Committee, LTD 17

FOREWORD

This Indian Standard (Part 1) was adopted by the Bureau of Indian Standards, after the draft finalized by the Printed Circuits Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

This standard was originally published in 1970 and underwent first revision in 1983. The standard is being revised to bring it in line with latest technological developments in this field.

In this revision assistance has been derived from following documents:

IEC Pub 249-1 Amend 1. Base materials for printed circuits : Part 1 Test methods. International Electrotechnical Commission.

IEC Doc 52 (Sectt) 285 Draft Amendment to Publication 249 : Base materials Part 1 : Test methods. Measurement of glass transition temperature using differential scanning analysis.

IEC Doc 52 (Sectt) 286 Draft Amendment to Publication 249 : Base materials Part 1 : Test methods. Measurement method for glass transition temperature using thermomechanical analysis.

IEC Doc 52 (Sectt) 287 Draft Amendment to Publication 249 : Base materials Part 1 : Test methods. Measurement of cure factor.

IEC Doc 52 (C. O.) 319 Amendment to Publication 249-1 and to publication 249-2 Specifications No. 1, —2, —3, —4, —5, —7, —9, —10, —12 and —14.

IEC Doc 52 (C. O.) 52 Draft Amendments and Additions to IEC Publication 249-1 : Base materials for printed circuits Part 1 : Test methods.

IEC Doc 52 (Sectt) 268 Draft Proposal for additional test — Measurement method of coefficient of linear thermal expansion.

IEC Doc 52 (Sectt) 284 Draft Amendment to IEC Publication 249-1 and 249-2 1 to 7, 9 to 12 and 14 : Bow and twist after etching and heating — Test methods and temperature requirements.

For the purpose of deciding whether a particular requirement to this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of specified value in this standard.

Indian Standard

SPECIFICATION FOR METAL-CLAD BASE MATERIALS FOR PRINTED CIRCUITS FOR USE IN ELECTRONIC AND TELECOMMUNICATION EQUIPMENT

PART 1 GENERAL REQUIREMENTS AND TEST

(Second Revision)

1 SCOPE

1.1 This standard (Part 1) prescribes general requirements and methods testing electrical, mechanical and other properties of metal-clad base materials in sheet form for application in the field of printed circuits in telecommunication and allied electronic equipment, irrespective of the nature of the insulating base material.

1.2 The methods given herein for the preparation of test sample and specimens are complete for copper-clad materials only. They may be expanded in future to cover materials clad with other metals.

1.3 This standard also covers multi-layer metal-clad base materials.

2 REFERENCES

2.1 The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY

3.0 For the purpose of this standard, the following definitions shall apply in addition to those specified in IS 1885 (Part 6) : 1978.

3.1 Type Tests

Tests carried out to prove conformity with the requirements of this standard. These are intended to check the general qualities and design of a given type of base material.

3.2 Acceptance Tests

Tests carried out on samples selected from a lot for the purpose of acceptance of the lot.

3.2.1 *Lot*

All metal-clad base materials of the same type, category and rating, manufactured by the same factory, during the same period, using the same process and materials.

3.3 Routine Tests

Tests carried out on each specimen to check the requirements which are likely to vary during production.

NOTE – These tests may be carried out in the presence of the purchaser.

4 MARKING

4.1 The manufacturer's name or trade-mark shall be indelibly marked on the base material at every 50 mm interval in both directions.

4.2 The following information shall be appropriately indicated on each sheet in ink or on label at one corner:

a) Manufacturer's name and/or trade-mark;
b) Manufacturer's code number or batch number;
c) Date of manufacture;
d) Any other marking as agreed to between the purchaser and the manufacturer;
e) Country of manufacture; and
f) In case of fire retardant type of materials, the markings on the sheet shall be in red colour.

4.2.1 The marking shall not be obliterated by normal processing nor shall it effect the physical and electrical properties of the base material. The labels shall remain securely affixed during normal handling of the sheet but readily removable prior to fabrication. The ink, if used, shall be of non-corrosive type and shall remain legible during normal handling but readily removable prior to fabrication indicating horizontal or vertical burning grade.

4.3 Marking shall be printed so as to indicate the machine direction of the filling material.

4.4 The metal-clad base material may also be marked with the Standard Mark.

5 TESTS

5.1 Classification of Tests

5.1.1 *Type Tests*

5.1.1.1 *General*

Unless otherwise specified four pieces of approximately 1.5 m^2 of metal-clad base material cut from four different sheets of each type and category shall be supplied for the purpose of type tests.

5.1.1.2 *Sequence of type tests*

The sequence of test will be in accordance with Table 1.

Table 1 Dimensions and Number of Specimen Required for Type Tests

(*Clauses* 5.1.1.2 *and* 5.2.4)

Sl No.	Tests	No. of Samples	Size of Specimen (mm)
(1)	(2)	(3)	(4)
A	ELECTRICAL TESTS		
	i) Resistance of foil	4	25 ± 0.2 x 330
	ii) Surface resistance and volume resistivity:		
	After damp heat (steady state)	4	100 x 100
	At elevated temperature	4	100 x 100
	iii) Dielectric breakdown:		
	Short time test	1	50 x 75
	Step by step test	3	50 x 75
	iv) Volume permitivity and loss tangent	4	100 x 100
	v) Q (Resonance)	8	32 x 75
	vi) Arc resistance	4	50 x50
	vii) Surface corrosion	4	100 x 100 Length 24
	viii) Corrosion at edge	4	Width to suit apparatus
B	NON-ELECTRICAL TESTS ON CLAD BASE MATERIAL		
	i) Dimension of whole sheets	All	Full sheet
	ii) Rectangularity of cut panels	All	460, *Max*
	iii) Size tolerances for sheets	All	Nominal size
	iv) a) Surface finish of laminates:		
	Scratches Pits Identation Pin holes Inclusion	All	Full sheet
	b) Finish of metal foil	1	300 x 300
	v) Mass of metal foil	1	100 x 100
	vi) Punchability	2	80 x 300
	vii) Dimensional stability	3	300 x 300
	viii) Bow	All	Full sheet + 1 (300 x 300)
	ix) Twist	All	Full sheet
	x) Bow after etching and heating	1	300 x 300
	xi) Twist after etching and heating	1	300 x 300
	xii) Solderability	1	100 x 100
	xiii) Blistering after heat shock	1	100 x 100
	xiv) Peel strength:		
	After heat shock After dry heat After exposure to solvent vapour After exposure to simulated plating condition At high temperature After temperature cycling	4 strips	75 ± 1 x 50 ± 1 for each test
	xv) Pull of strength	10 lands	Any convenient size
	xvi) Mould growth (when applicable)	4	50 x 50

Table 1 (*concluded*)

Sl No.	Tests	No. of Samples	Size of Specimen (mm)
(1)	(2)	(3)	(4)
C	NON-ELECTRICAL TESTS ON BASE MATERIAL		
	i) Flexural strength	5 in each of 2 directions	20 x 10 ± 0.5 or 20 x 25 ±0.5
	ii) Flammability (when applicable):		
	Horizontal burning of rigid materials	4	125 ± 5 x 13 ± 1
	Vertical burning of rigid materials	10	125 ± 5 x 13 ± 1
	Vertical burning of flexible materials	4	450 x 25
	iii) Water absorption	3	50 x 50
	iv) Coefficient of linear thermal expansion	3	Convenient size
	v) Measling	4	15 x 50
	vi) Glass transition temperature		
	a) Different scanning calorimetry	3	Suitable size
	b) Thermomechanical analysis	3	Suitable size
	vii) Cure factor	3	Suitable size

NOTE — Whenever four or multiple of four samples are required, number of samples shall be equally distributed to cut from each sheet.

5.1.2 *Acceptance Tests*

The acceptance tests shall be in accordance with Table 2. The AQL (percent defective) and inspection levels shall be specified in the detail specification.

Table 2 Acceptance Tests
(*Clasue* 5.1.2)

Group	Title of Test
(1)	(2)
O	Visual examination
A	Dimension and tolerance Surface finish : Pits Dents Pinholes Scratches Bow } as received Twist
B	Solderability Solder float (for glass apoxy) Unetched specimens Etched specimens Un-fluxed Fluxed
C	Peel strength After solder fleat At elevated temperature After exposure to plating solution Volume resistivity Surface resistivity Dielectric constant and dissipation factor

5.2 General Conditions for Test

5.2.1 *Atmospheric Conditions for Testing*

Unless otherwise specified all the tests shall be carried out under the standard atmospheric conditions as specified in IS 9000 (Part 1) : 1977.

5.2.2 *Material Process and Finish*

Metal-clad laminates shall be manufactured and processed in a careful and workman-like manner in accordance with sound engineering practice. The laminates shall be uniform and shall be free of wrinkles, blisters and other defects which will affect appearance and seviceability. All metal-clad laminates of the same type, composition and thickness shall be uniform in texture, finish and specified properties.

5.2.3 *Other Precautions*

During measurements the base material shall not be exposed to draughts, direct sun-rays and other influences likely to cause errors.

5.2.4 *Dimensions of Test Specimens with Number Required*

Numbers and dimensions of test specimens for each test are given in Table 1.

5.2.5 *Preparation of Test Sheets and Specimen from Metal-clad Base Material*

5.2.5.1 *Preparation of specimens*

Specimens shall be cut, sawed and machined from the sample sheet. A width of 12.7 mm from the edge shall not be used for specimens. When applicable, the direction of grain, lengthwise and crosswise, shall be clearly defined. For the peel strength test, specimens shall be cut from two diagonally opposite corners of each sample sheet. Further preparation shall be defined in the test method.

5.2.5.2 *Washing and printing to form test pattern*

If a test pattern is to be formed, the metal face of a sample of the sheet under test first be washed with water, an abrasive powder (for example, Grade 240 pumice) and, if necessary, trisodium phosphate until water will remain in an unbroken film covering the whole face.

The pattern shall be printed on the metal face by means of photoengraving or other technique giving the specified accuracy.

5.2.5.3 *Method of etching*

Etching whether for forming test patterns or for the complete removal of the foil, shall be carried out as per any of the following methods.

a) *By use of ferric chloride* – Etching shall be carried out with a spary or by an equivalent method, with an aqueous solution of ferric chloride of specific gravity 1.32 to 1.41 (35 to 42 Baume). The temperature of the solution shall be 24 to 38 °C.

   If a test pattern is being formed, the etching time shall be sufficient to produce a clear and distinct image.

   The etching time for foils of preferred mass per unit area shall not exceed those shown in the following table:

Nominal mass *of foil*, g/m² :	152	230	305	610	915
Etching time, *Max*, minutes :	6	6	7	14	21

   For foils of intermediate mass, the maximum etching time shall be determined by linear interpolation.

   For foils outside the given range, the maximum etching time shall be agreed between the purchaser and the supplier/manufacturer.

   If undesired particles of copper remain after the etching, the specimen shall not be used for testing.

   Immediately after it is etched, the specimen is washed in running tap water (at 15 to 35 °C) for 2 to 5 minutes.

   If required, immerse the specimen in 10 percent solution of oxalic acid in water at 15 to 35 °C for 15 to 20 minutes. The specimen shall then be washed in cold running water (at 15 to 35 °C).

   NOTE– In order to ensure the removal of etching residues on the board surface (which if not removed before drying may interfere in the electrical properties as well as cause soldering problems) the acid neutralization should be carried out, 5 to 10 percent solution of oxalic acid or hydrochloric acid may be used after ferric chloride etching.

   If the test pattern has been formed, the resist shall be removed by any suitable means, for example, by the use of pumice or other cleaning agents.

   NOTE– To remove the resist, the specimens are scrubbed with grade 240 pumice or wiped with lint free cloth moistened with a suitable solvent which does not effect the laminate.

   Any residue of pumice or other cleaning agent shall be washed off with brush under running tap water (of resistivity not less than 10 Ω. m) for as long as necessary to remove surface contamination (usually 15 to 30 minutes). The cleaning process shall be continued until water will remain in an unbroken film covering the whole metal face of the test specimen.

   The specimen shall then be rinsed three times, for 2 to 3 minutes each time, in different lots of distilled water (of resistivity not less than 1 000 Ω. m).

   Care shall be taken to minimize attack or abrasion of any adhesive layer or laminate by pumice or solvent.

   Specimen not involving use of resist need not be scrubbed.

b) *By use of ammonium persulphate* – Etching shall be done by use of a solution of 298 ± 10 g/1 of ammonium persulphate sulphuric and 15.5 ± 1 ml/1 of sulphuric acid (specific gravity 1.836). The temperature shall be maintained at 43 ± 3 °C).

   After etching the specimen shall be washed and dried as suggested in previous method [*see* **5.2.5.3** (a)].

5.2.5.4 Surface water shall then be removed from it and shall be dried of 4 hours ± 10 minutes at 55 ± 2 °C or for 1 h at 85 °C (for glass epoxy) in an oven.

5.2.5.5 All tests shall start within 3 weeks of removal from the oven. During this time, until preconditioning according to **5.2.1** is started, the specimens shall be kept in a suitable container.

5.2.5.6 *Visual examination of prepared sample*

When specimens are prepared as above, the metal foil shall be readily removable from clad surfaces of the laminate. There shall be not more than one piece of residual metal per 0.5 m^2 of surface examined and this piece shall not have an area greater than that of a circle 0.1 mm in diameter. There shall be no evidence of other metallic particles or foreign materials on the etched surface of the based laminate or embedded therein. The surface of the base laminate shall show no evidence of weave exposure or texture exposure.

5.2.5.7 *Precautions to be taken in certain electrical tests*

In certain electrical tests it is necessary to guard against contamination of the test specimen. During these tests, handling of the specimens should be kept to a minimum, the specimens being held by the edges or by the connecting wires as appropriate. Clean rubber or polythene gloves shall be used.

The use of fixtures with spring loaded contacts removes the need of connecting wires, solders and fluxes. If connecting wires are being attached, care shall be taken to prevent any contamination of the surface of the insulating base material by solder flux. A mask should be used for this purpose.

The use of solvents for removing contaminants may result in spreading the contaminants over the whole surface.

The relevant clauses show where these precuations are needed.

6 ELECTRICAL TESTS

6.1 Resistance of Foil

6.1.1 *Test Specimen*

The test specimen shall be a strip of metal clad base material 25 ± 0.2 mm wide and approximately 330 mm long, cut from the sheet under test. Its thickness shall be that of sheet under test. Four specimens shall be tested.

6.1.2 *Procedure*

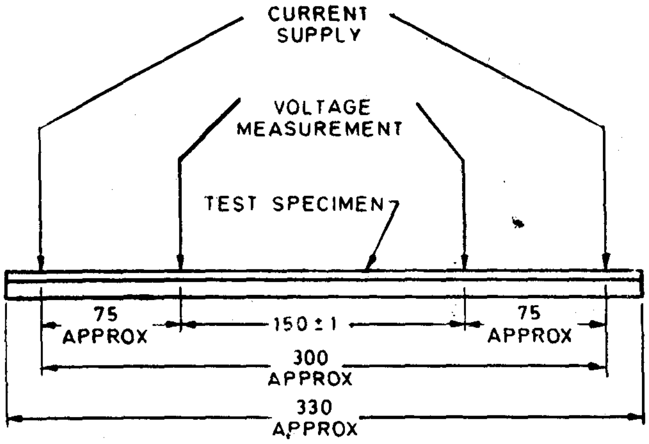
The test specimen shall be placed with its foil surface in contact with line or point contacts 150 ± 1 mm apart. Line contacts shall touch the foil across its whole width and shall be at right angles to the major axis of the test specimen. The distance between current contacts shall be 300 mm, the potential contacts shall be 150 ± 1 mm apart and at equal distance from the current contacts as shown in Fig. 1.

The resistance of the foil between the contacts shall be measured. The current shall be kept small enough to avoid heating the specimen appreciably; its maximum value shall be given in the relevant specification .

The ambient temperature shall be measured and the measured resistance shall be corrected to 20 °C.

For the copper of 96 percent conductivity the correction factor is given by:

$$K = \frac{1}{1 + 0.003\,78\,(t - 20)}$$



All dimensions in millimetres.

FIG. 1 ARRANGEMENT OF THE POSITION OF CURRENT SUPPLY AND VOLTAGE MEASUREMENT

The values of *K* for temperature between + 15 °C and + 35 °C are given below:

Temperature (°C)	*Correction Factor* (*K*)
15	1.019
16	1.015
17	1.011
18	1.008
19	1.004
20	1.000
21	0.996
22	0.992
23	0.989
24	0.985
25	0.981
26	0.978
27	0.974
28	0.971
29	0.967
30	0.964
31	0.960
32	0.957
33	0.953
34	0.950
35	0.945

6.1.3 *Report*

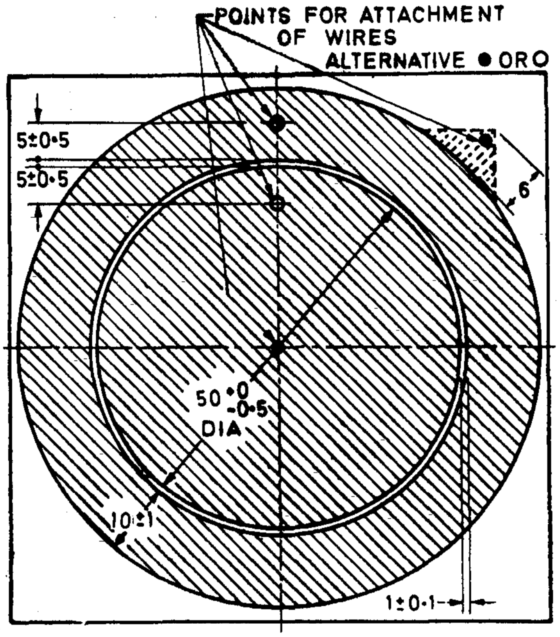
The maximum value of the four resistances measured shall be reported as the resistance of the foil.

6.2 Surface Resistance and Volume Resistivity

6.2.1 *Test Specimen*

The test specimen shall be a piece of metal-clad base material cut from the sheet under test which shall be big enough for a square of 100 ± 5 mm side to be obtained from it and be before it is printed, it shall be of the thickness of the sheet.

If the base material is clad with metal on one side, it shall be printed on this side with the ring and disk pattern of Fig. 2 by the appropriate method of **5.2.5.**



All dimensions in millimetres.

FIG. 2 RING AND DISK PATTERNS

On the other side the whole of the surface shall be coated with an air-drying conductive silver paint according to Fig. 3 and 4.

If the base material is clad with metal on both sides, it shall be printed on one side with the ring and disk pattern of Fig. 2 and on the other side with the disk pattern of Fig. 3 and 4 by the appropriate method of **5.2.5.**

Connecting wires or spring loaded contacts may then be attached to the ring and disk.

For specimens shall be tested.

6.2.2 *Procedure*

If there is no metal foil on the reverse face of the specimen, three electrode system as shown in Fig. 3 and 4 shall be completed. Neither evaporated nor sputtered metal electrodes shall be used. Conductive silver paint may be used.

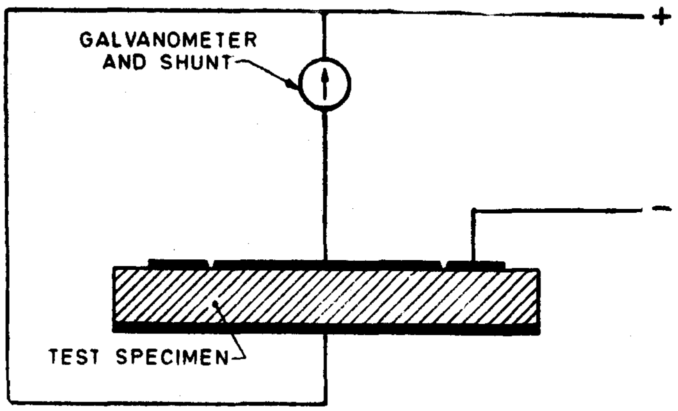


FIG. 3 THREE-ELECTRODE ARRANGEMENT FOR SURFACE RESISTANCE MEASUREMENT

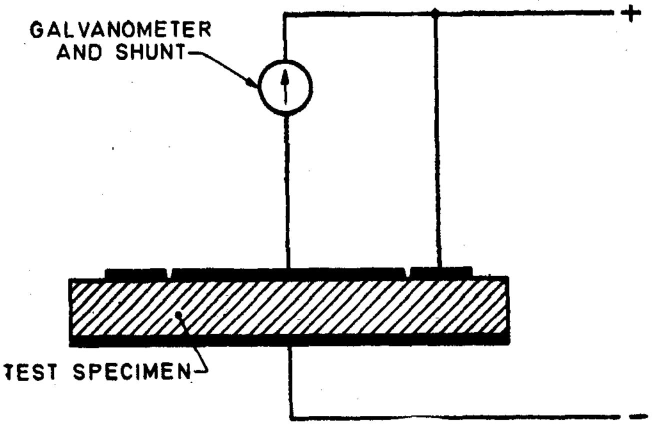


FIG. 4 THREE-ELECTRODE ARRANGEMENT FOR VOLUME RESISTANCE MEASUREMENT

When the leads are required to be attached to the conductive silver plate, this may be accomplished by the use of conductive adhesive having room temperature cure characteristics.

The electrode on the reverse face shall cover the whole of that face.

The resistance between the ring and the disk shall be measured by the method described in **5.1, 5.2** and **5.8** of IS 3396 : 1979.

The above-mentioned resistance measurement shall be made at 500 ± 50 V dc after rectification for 1 minute. The electrical connections to the test specimen shall be made as shown in Fig. 3. The apparatus used for measuring resistance shall be such that the error of the measurement is less than ± 50 percent.

6.2.2.1 *Report*

The minimum value of the four resistance measurements shall be reported as the surface resistance of the sample under test. It shall be expressed in MΩ.

The volume resistivity shall be calculated by the method given in IS 3396 : 1979 and the minimum of the four values shall be reported. It shall be expressed in $M\Omega^{-m}$.

6.2.3 *Surface Resistance and Volume Resistivity after Damp Heat (Long Term)*

The specimen and method as described in **6.2.1** and **6.2.2** shall be used. The specimen shall be subjected to appropriate severity of damp heat including recovery, according to IS 9000 (Part 4) : 1979, as given in relevant specification. The measurements shall be made at the end of damp heat period or before removal of the specimen from the humidity chamber or at the end of the recovery period, as specified in relevant detail specification.

6.2.3.1 *Report*

The minimum of the four measurements shall be reported after appropriate calculations as in **6.2.2.1**.

It shall be stated whether the measurements have been made out within the chamber or after recovery.

6.2.4 *Surface Resistance and Volume Resistivity at Elevated Temperature -*

The test specimen and method as described in **6.2.1** and **6.2.2** shall be used. The specimen shall be subjected to dry heat conditioning in accordance with IS 9000 (Part 3) : 1977 for one hour. Measurement shall be made at the end of this time while the specimen is still in the chamber. The test temperature shall be that indicated in the relevant specification. There shall be no recovery.

6.2.4.1 *Report*

The minimum value of the four results shall be reported along with the temperature at which the measurements have been made.

6.3 Dielectric Breakdown

6.3.1 *Parallel to Laminations*

a) *Test specimen* — Test specimen shall be 50 mm wide and 75 mm long pieces of laminates under test. These shall be etched to remove metal foils by procedure given in **5.2.5**. Two holes shall be drilled, after etching, of 4.76 mm diameter on the larger axis, with their centres 25.4 mm apart.

b) *Test preparation* — Electrodes used shall be 75 mm long having a taper of 6.35 mm per 304.8 mm and a diameter of 5.5 mm at the large end. Using standard tapered pin reamer, holes shall be reamed to a sufficient depth to allow the pins to extend approximately 38 mm from the small end of the hole. The electrodes shall be inserted after the specimens have been conditioned. To decrease the tendency of flash over, spheres having 12 mm diameter shall be placed on the extremities of the tapered pins. The test shall be carried out under oil at a frequency from 50 Hz to 70 Hz.

c) *Test procedure*

   i) *Short time test* — The voltage shall be increased from zero to breakdown voltage at the rate of 500 V per second. If the short time test is not required, one additional specimen shall be prepared and subjected to the short time test to provide the initial voltage and increments of increase for the step by step test.

ii) *Step-by-step test* —The initial voltage shall be 50 percent of the breakdown voltage obtained on the short time test and it shall be increased by increments as specified below. It shall be held at each step for one minute and then change to next higher step within 10 seconds. This process shall be continued till breakdown.

Breakdown Voltage	*Increment of Increase*
kV	kV
12.5 or less	0.5
Over 12.5 to 25 inclusive	1.9
Over 25 to 50 inclusive	2.5
Over 50 to 100 inclusive	5.0
Over 100	10.0

6.3.2 *Perpendicular to Lamination*

Under consideration.

6.4 Volume Permittivity and Volume Loss Tangent

6.4.1 *Test Specimen*

The test specimen shall be as described in **6.2.1** and formed specimen shall be tested.

6.4.2 *Procedure*

If required, each specimen shall first be subjected to damp heat (steady state) test of appropriate severity as specified in relevant detail specification, as per IS 9000 (Part 4) : 1979. It shall then be removed from the recovery conditions.

Electrodes shall be applied or completed, except that neither evaporated nor sputtered electrodes shall be used.

The relative permitivity and the loss tangent of the material between electrodes shall then be measured at the frequency of 1 MHz, of any suitable method described in IS 4486 : 1967.

6.4.3 *Report*

The average values and maximum values both of the four permittivities and of the four loss tangents so measured shall be reported along with conditioning, if any.

6.5 '*Q*' (Resonance)

6.5.1 *Test Specimen*

The test specimen shall be a piece of metal-clad base material under test. The pattern shown in Fig. 5 shall be etched on it by method given in **5.2.5**. The specimens shall be cleaned with a fine grade of non-conductive mineral powder such as pumice or alumina. Base wire test specimens. Once soldered, the specimens shall be scrubbed in technical grade isopropyle alcohol to remove all traces of rosin flux and other contaminants. Eight specimens shall be used.

6.5.2 *Test Procedure*

6.5.2.1 *Preconditioning*

The etched specimen shall be dipped in water at room temperature for one hour and shall be allowed to dry at room temperature before starting the test.

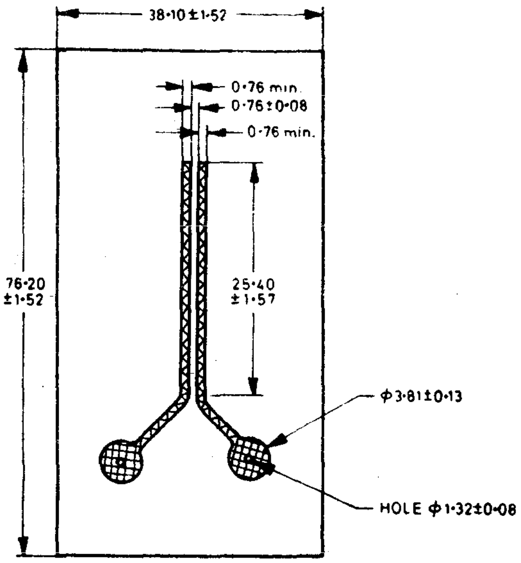


FIG. 5 '*Q*' TEST PATTERN

'*Q*' of the specimens shall be measured at 1 MHz, 50 MHz and 100 MHz. The test shall be started 4 hours after removing the specimens from the water and completed within 1 hour using the following procedure.

'*Q*' meter shall be resonated by resonance rise method without any test specimen. The voltmeter reading shall be recorded as Q_1 and capacitance reading as C_1.

The test specimen shall then be connected in parallel to the *Q* circuit and the *Q* meter shall again be resonated. The measurement leads shall be equal in length and as short as practicable to reduce lead inductance while performing the test. The voltmeter reading at resonance shall be recorded as Q_2 and capacitance reading as C_2.

The '*Q*' of specimen shall be calculated by using the formula:

$$Q = \frac{Q_1 Q_2 (C_2 - C_1)}{(Q_1 - Q_2) C_1}$$

6.5.3 *Report*

The average value of *Q* for eight specimens shall be reported.

6.6 Arc Resistance

6.6.1 *Test Specimen*

The specimen shall be a square of 50 mm cut from the sheet under test. The specimens shall be etched in accordance with **5.2.5** to remove the metal foil completely. Four specimens shall be tested.

6.6.2 *Test Equipment*

The testing for arc resistance requires a source of high voltage and low current with facility to interrupt the current at required time interval. A suitable circuit is shown in Fig. 6. The equipment shall be able to provide 12 500 V across the electrodes with a current of 60 mA.

The resistor and inductors are connected in series with electrodes to suppress parasitic high frequency in the arc circuit. The interrupter shall be capable of opening and closing the primary circuit according to the schedule as given in Table 3 with an accuracy of ± 1/120 seconds. The timer is used in the circuit to record the time taken in failure. The circuit shall be protectively interlocked to avoid danger of high voltage discharge from transformer.

6.6.3 *Electrodes*

The electrodes shall be made from 0.15 mm thick stainless steel by cutting 12.7 x 25.4 mm rectangle. The edges shall be cleanly cut so as to be free of burrs. The strip electrodes shall be bent slightly in the middle of the longer dimension so that an angle of approximately 160° is formed when the electrodes lie on a flat surface.

Alternatively tungsten rod electrodes with a diameter of 2.4 mm and length about 19.1 mm shall be used. It shall be free from cracks, pits or rough spots shall be cleaned by heating to a dull red colour, rubbing on a block of alkali nitrate and quenching immediately in water.

NOTE — For values of arc resistance greater than 180 seconds, the use of the tungsten rod electrodes is recommended because the corners of the stainless steel strip electrode appreciably under such conditions.

6.6.4 *Test Procedure*

The specimen shall be placed horizontally with ample air space below it and electrodes shall be applied using proper jigs. The pressure of electrodes on the specimen shall be about 500 mN. The electrodes shall be 6.4 mm apart making an angle of 45° to the line joining the corners. The electrode assembly shall be protected by a transparent draft shield.

The test sequence shall be as given in Table 3. At the end of each minute, increase the severity in steps as given in Table 3. In the earlier steps, an interrupted arc is used to obtain a less severe condition than the continuous arc. [A current less than 10 mA produces an unsteady (flaring) arc.]

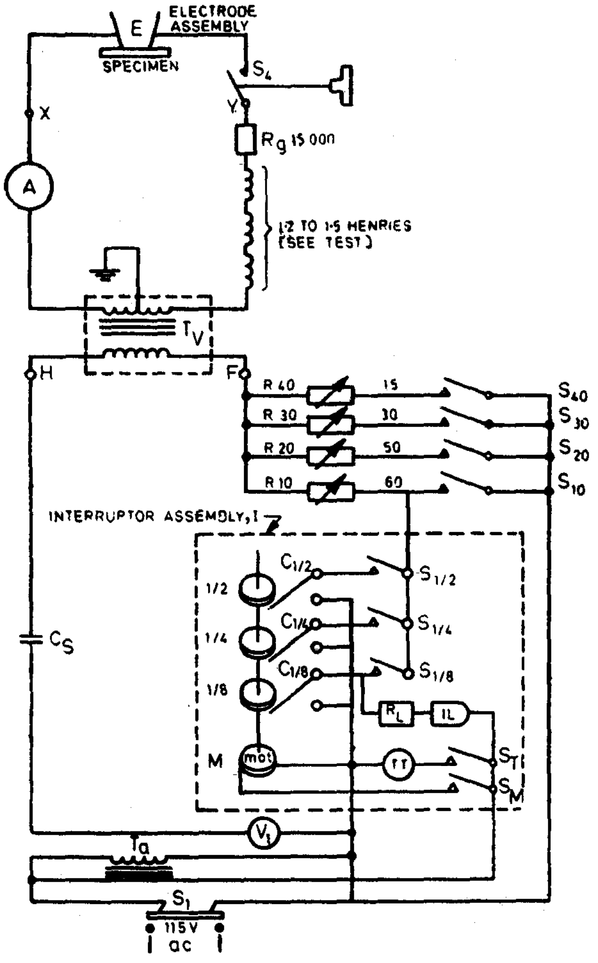


FIG. 6 CIRCUIT FOR TESTING OF ARC RESISTANCE

Table 3 Sequence of One Minute Current Steps

(*Clauses* 6.6.2 *and* 6.6.4)

Step	Current mA	Time Cycle	Total Time s
0.125 - 10	10	0.25 s on, 1.75 s off	60
0.25 - 10	10	0.25 s on, 0.75 s off	120
0.50 - 10	10	0.25 s on, 0.25 s off	180
10	10	Continuous	240
20	20	Continuous	300
30	30	Continuous	360
40	40	Continuous	420

The arc shall be observed from a position on a level with the surface of specimen so as to be able to notice the changes in arc. If the arc flares irregularly the circuit constants shall be checked.

The failure shall be noted when a conducting path is formed across the dielectric and the arc disappears into the material. At the time of failure, the arc current shall be interrupted and the time taken in failure shall be noted from the timer.

6.6.5 *Report*

The average minimum time taken in failure of arc resistance shall be reported with the type of electrode assembly used.

6.7 Surface Corrosion

6.7.1 *Test Specimen*

The test specimen shall be a piece of metal-clad base material cut from the sheet under test. It shall be big enough for a square of 100 mm side to be cut from it and before it is printed it shall be of the thickness of the sheet under test. It shall be printed on one side with ring and disk pattern of Fig. 2 by the appropriate method of **5.2.5.** If the sheet is clad with metal on both sides the metal on the other side of the specimen shall be completely removed by the appropriate method of **5.2.5** or shall be left intact. Connecting wires shall be attached to the ring and disk.

Four specimens shall be tested.

6.7.2 *Procedure*

If there is no metal foil on the reverse face of the specimen, a three electrode system shall then be used (*see* Fig. 3). Neither evaporated nor sputtered metal electrodes shall be used. When leads are required to be attached to silver plate this may be accomplished by the use of conductive adhesive having room temperature curing characteristic.

The electrode on the reverse face shall cover the whole of that face.

The specimen shall then be subjected to damp heat of appropriate severity (21 days) according to IS 9000 (Part 4) : 1979.

During the whole period a potential difference of 100 V dc shall be applied between the ring and the disk through a resistor such that the current does not exceed 1 mA. The specimen shall be removed from the conditioning chamber and inspected for corrosion products.

6.7.3 *Report*

It shall be stated whether corrosion products have been observed.

6.8 Corrosion at Edge

6.8.1 *Test Specimen*

The specimen shall be a piece of metal-clad base material cut from the sheet under test. It shall be 24 mm long with suitable width. Four specimens shall be tested.

6.8.2 *Test Procedure*

The test shall be carried out in accordance with IS 8516 : 1977.

6.8.3 *Report*

The degree of corrosion, as assessed in accordance with IS 8516 : 1977 shall be reported.

7 NON-ELECTRICAL TESTS ON METAL-CLAD BASE MATERIAL

7.1 Dimensions of Whole Sheet

The dimensions of the sheet shall be measured to an accuracy one order better than the tolerance. The thickness shall be measured to 10 locations.

7.1.1 *Length and Width*

Unless otherwise specified, the manufacturers standard steel strips between 500 mm in length and 500 mm and 2 500 mm in length and between 500 mm and 1 300 mm in width shall be acceptable. The tolerances for length and width for such standard sizes shall be ± 6 mm per 200 mm but not exceeding ± 25 mm on overall length and width.

In case of smaller sizes cut from standard sheet sizes of manufacturer, the dimensional tolerances are to be agreed to between the manufacturer and the user.

7.1.2 *Thickness*

Nominal thickness and tolerances shall be as specified in the relevant specification.

7.2 Rectangularity of Cut Panels

7.2.1 *Object*

To measure the deviation from 90° on corners of rectangular cut-to-size panels of maximum dimension less than 460 mm.

7.2.2 *Procedure*

The panel shall be checked against a square test fixture of dimension large enough to encompass the maximum dimension of the panel.

Each corner of the panel shall be checked by holding the panel against one face of the square test fixture with its corner in the corner of the fixture and the maximum distance between the adjacent panel edge and the adjacent fixture edge measured with a taper gauge or feeler gauge.

7.2.3 *Report*

The report shall state:

1. the maximum deviation from 90° as mm/m of panel length, and
2. the dimensions of the panel.

7.2.4 *Rectangularity of Cut Panels*

The cut panels shall have rectangularity as given in Table 4.

Table 4 Rectangularity of Cut Panels

Property	Test Method	Requirement	
	(Sub-clause)	Coarse (mm/m)	Normal (mm/m)
Rectangularity of cut panels	6.2	3	2

7.3 Size Tolerances

7.3.1 *Size Tolerances for Sheets*

The size of the sheets as delivered by the supplier shall not deviate from the nominal size by more than $^{+10}_{-0}$ mm.

7.3.2 *Size Tolerances for Cut Panels*

For panels cut to size according to the purchaser's specification, the following tolerances for length and width given in Table 5.

Table 5 Size Tolerances for Cut Panels

Panel Size	Tolerance ± (mm)	
mm	Normal	Coarse
Up to 300	2	0.5
Over 300 to 600		0.8
Over 600		1.6

NOTE — The specified tolerances include all deviations caused by cutting the panels.

7.4 Surface Finish

7.4.1 *Appearance of Metal Foil Surface of Metal-Clad Base Material Sheet*

This test is applicable only where a high quality surface finish is essential for precious metal plating or fine line etching. The method deals with imperfections in the metal-clad surface. Where the assessment of imperfections is too time consuming for production testing, visual comparison with standard samples may be used. The imperfections have been classified into groups and sizes.

7.4.2 *Methods of Inspection for Surface Defects*

A suitable method or inspection is as follows:

A sheet under test is placed on a flat horizontal surface and inspected for defects under suitable illumination.

Suitable illumination is provided by a horizontal tubular white fluorescent light source, positioned as shown in Fig. 7 parallel with one edge of the sheet, above its plane, so that the ratio of the distance *x* to distance *y* is not greater than 0.27. Direct sunlight is excluded. (An even illumination of the order 200 1x to 400 1x is recommended.)

The sheet is inspected with the light source, parallel in turn with the two adjacent edges. Inspection is done looking towards the light source, in such a way that the direct light from the source is not seen. A screen in front of the light source may be used to achieve this.

The depth of scratches is measured by means of a suitable instrument. The length and width of other defects are measured with a greticule and lense.

7.4.3 *Method of Inspection for Surface Finish*

Surface finish shall be determined by a profilometer using a 4.4 N/m^2 tracing pressure with a 0.8 mm cut off. Any other instrument having equal or greater accuracy may be used. At least 3 measurements in each direction shall be made at right angles to each other. The 6 measurements shall be averaged. The measurement shall be specified in the detail specification.

7.5 Mass of Metal Foil

7.5.1 *Test Specimen*

The specimen shall be a sample of the metal-clad base material under test and shall be a square of side length 100 mm. One specimen shall be used.

7.5.2 *Procedure*

The dimensions of the specimen shall be measured to an accuracy of 0.1 mm and used to calculate its area.

The specimen shall be preconditioned for 24 hours at 27 °C and 65 percent relative humidity and then weighed to an accuracy of 0.002 g.

The metal foil or foils shall then be completely removed by the appropriate method of **5.2.5** and the specimen shall again be conditioned for a further 24 hours at 27 °C and 65 percent relative humidity, before reweighing as before.

Materials clad with metal foil on both sides shall be tested as above unless it is necessary to determine the mass of individual foils, for example, when different foils are used on opposite sides or in case of dispute. In these cases only, separate specimen shall be used to determine the foil mass on each side, and the foil on the reverse side shall be protected by a suitable resist applied before the first period of preconditioning.

The mass per unit area of metal foil shall be calculated by dividing the difference between the two measured masses by the measured area of the specimen. In the case of materials clad on both sides with similar foils, the mass per unit area of the individual foils be taken as half the total obtained.

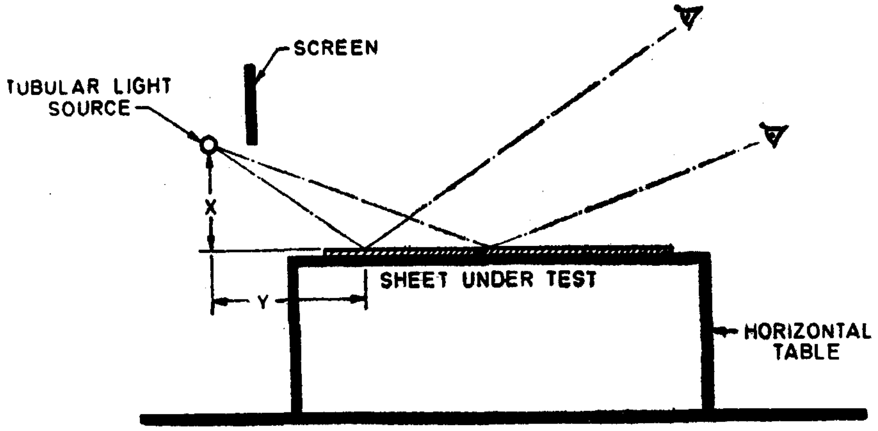


FIG. 7 INSPECTION FOR SURFACE DEFECTS

7.5.3 *Requirements*

The mass per unit area of the metal foil shall be as specified in the relevant detail specification.

7.6 Punchability

7.6.1 The test method and requirements shall be as agreed between the manufacturer and the purchaser.

7.7 Dimensional Stability

7.7.0 *General*

The purpose of this test is to provide the information on the linear dimensional changes of metal-clad base material which may occur during processing, particularly after etching and heat treatment.

7.7.1 *Test Specimen*

Three specimens shall be used. If the size of sheet as manufactured exceeds 300 mm in both directions each shall be a square of 30 mm approximate side length, cut from a sheet of the material under test. Three specimens shall be cut from different locations across the sheet as shown in Fig. 8.

When possible, one side of the specimen shall be cut paralled to the machine direction and it shall be so identified.

Suitable markings such as scribed or printed crosses or holes shall be put in each corner of the specimen, approximately 20 mm from the edges so that they form a square of side length 260 ± 5 mm. These markings or holes shall be numbered 1, 2, 3 and 4 (*see* Fig. 9).

For materials with a width between 140 mm and 300 mm, the specimen shall be a square with a side length equal to the width of the material. The 4 markings shall form a square of side length approximately 4 mm less than the width of the material.

For the materials supplied with a width narrower than 140 mm, the specimen shall be approximately 140 mm long and not less than 25 mm wide and only two markings 1 and 2 shall be made. The distance between them shall be approximately 100 mm.

7.7.2 *Procedure*

Optical or mechanical methods may be used. The method shall be capable of repeatability of measurement with an error not exceeding 13 µm. The samples shall be measured before and after processing.

7.7.3 *Specimen Conditioning*

If required specimen shall be maintained under the standard atmospheric conditions for at least 18 hours before any measurements are made.

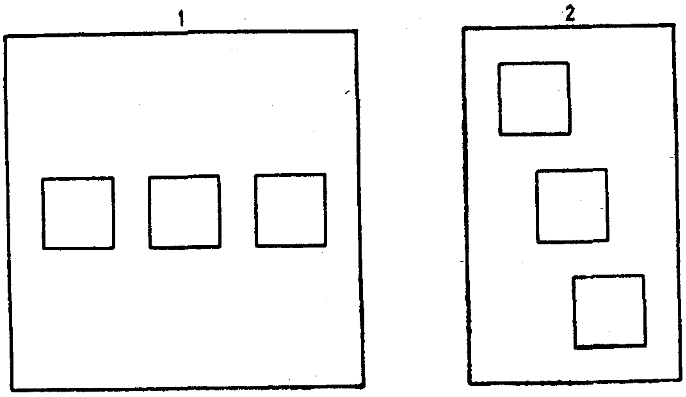


FIG. 8 LOCATION OF SPECIMENS ON ORIGINAL SHEET

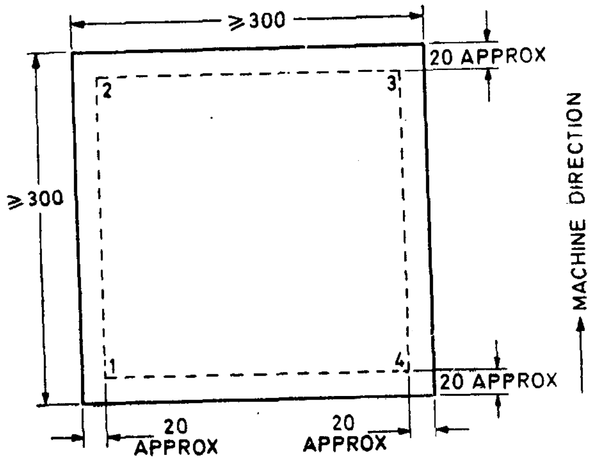


FIG. 9 LOCATION OF MARKS ON SPECIMEN

7.7.4 *Measurement*

The distance shall be measured between the following marks labelled as indicated in Fig. 9 (1 to 2, 2, to 3, 3 to 4 and 4 to 1).

For each specimen the average of the distance measured between points 1-2 and 3-4 shall be used for determining the dimensional change in one direction and the average of the distances between points 2-3 and 4-1 for determining the dimensional changes in the direction at right angle. Where the machine direction is known, it shall be stated which of the two dimensional changes correspond to the machine direction.

The specimen shall be kept flat during measurement. All measurement shall be made under the standard reference conditions.

7.7.5 *Test Sequence*

The specimen shall be tested in the following sequence:

a) Pre-conditioning according to **8.7.3**;
b) Initial measurements according to **8.7.4**;
c) Masking – Prior to etching the reference masking or holes shall be masked with etched resisting squares with side length not exceeding 30 mm;
d) Process Step I – Etching, washing and drying shall be done according to **5.2.5**;
e) Pre-conditioning according to **7.7.3**, if required;
f) Measuring according to **7.7.4**;
g) Process Step II – Heating specimen at specified elevated temperature as given in relevant detail specification and for a duration of 45^{+5}_{-0} minutes.
h) Cooling to the standard reference temperature;
j) Measuring according to **7.7.4**,
k) Reconditioning according to **7.7.3**, if required (to overcome effects of Process Step II);
m) Process Step III – Temperature cycling as per relevant detail specification, if specified;
n) Cooling to the standard reference temperature; and
p) Measuring according to **7.7.4**.

7.7.6 *Report*

The report shall state:

a) Size of the specimen;
b) Details of the process step; and
c) Dimensional change for each specimen in relation to the initial dimensions for each direction of the sheet and for each process step.

The dimensional change shall be expressed in micrometers per millimetre (µm/mm), followed by the word 'shrinkage' or 'expansion'. Permissible value shall be as per the relevant specification.

7.8 Bow or Warp

7.8.0 This test is not applicable for sheets thinner than 0.8 mm.

7.8.1 *Test Specimen*

Bow shall be measured on all full sheets and on one cut square of side 300 mm.

7.8.2 *Test Apparatus*

A straight edge and a dial micrometer, thickness gauge or any similar device accurate to 0.03 mm shall be used.

7.8.3 *Procedure*

The sheet or panel shall be placed unrestrained on a flat horizontal surface with its predominantly convex surface upward. The maximum vertical distance at the edge between the flat horizontal surface and the concave side of the material shall be determined using a taper or feeler gauge.

The result shall be expressed as a percentage of the length of the side of the sheet or panel, corresponding to the measured value.

The value obtained on materials metal-clad on one side only shall be followed by "pos" if the metal-clad face is convex, or "neg" if the metal-clad is concave.

7.8.4 *Report*

The report shall state:

i) The maximum bow in percentage with the designation of the length of the side of the sheet or panel referring to the percentage value including any reference to "pos" or "neg";

ii) The dimensions of the sheet or panel and the copper foil thickness on both sides.

7.9 Twist

7.9.0 The test specimen and apparatus used for measurement of bow as mentioned above shall be used. This test is also not applicable to sheets of thickness less than 0.8 mm.

7.9.1 *Procedure*

The sheet or panel shall be placed unrestrained on a flat horizontal surface with its predominantly convex surface upward and with three corners of the lower side in contact with the surface. The vertical distance from the flat horizontal surface to the fourth corner of the concave side of the material shall be measured using a taper gauge or feeler gauge.

The result shall be expressed as a percentage of the diagonal measurement of the sheet or panel.

7.9.2 *Report*

The report shall state:

1. The twist in percentage;
2. The dimensions of the sheet or panel, and the copper foil thickness on both sides.

7.10 Bow After Etching and Heating

7.10.1 *Object*

To measure the deviation from flatness of a copper clad sheet after etching and heating in a direction parallel to its edges simulating printed circuit processing steps.

7.10.2 *General*

This test is not applicable to sheets thinner than 0.8 mm.

7.10.3 *Test Specimen*

The test specimen shall be a square of 300 mm side length cut from a sample of the metal-clad base material under test.

One specimen shall be used.

7.10.4 *Procedure*

7.10.4.1 *Etching*

The specimen shall be etched according to the appropriate method of **5.2.5** form a pattern of parallel conductors with 0.4 mm width and 0.4 mm spacings. For base materials with copper foils on both sides the conductors on one side shall be perpendicular to the conductors on the other side.

7.10.4.2 *Heating*

The specimen shall be placed unrestrained on a flat horizontal surface and shall be subjected to dry heat as specified in IS 9000 (Part 3) : 1977 but at the temperature indicated in the relevant material specification and for a duration of 45 $^{+5}_{-0}$ minutes.

7.10.4.3 *Conditioning*

The specimen shall be maintained under the standard atmospheric conditions for "referee" tests specified in IS 9000 (Part 1) : 1977 for at least 18 hours.

7.10.4.4 *Measurement*

Bow shall be measured as described in **7.8.3**.

7.10.4.5 *Report*

The report shall be as described in **7.8.4**.

7.11 Twist After Etching and Heating

7.11.1 *Object*

To measure the deviation from flatness of a copper clad sheet after etching and heating along the diagonals simulating printed circuit processing steps.

7.11.2 *General*

This test is not applicable to sheets thinner than 0.8 mm.

7.11.3 *Test Specimen*

The test specimen shall be as described in **7.10.3**.

7.11.4 *Procedure*

Etching, heating and conditioning shall be as described in **7.10.4.1**, **7.10.4.2** and **7.10.4.3**. This shall be measured as described in **7.9.1**.

7.11.5 *Report*

The report shall be as described in **6.9.2**.

7.12 Solderability

The test shall be carried out in accordance with **3** of IS 9000 (Part 18) : 1981.

7.13 Blistering After Heat Shock

7.13.1 *Test Specimen*

The test specimen shall be a sample of the metal-clad base material under test, and before it is printed its thickness shall be that of the material. It shall be approximately 100 mm square and shall be printed by the appropriate method of **4.2.5** with the ring and disk pattern of Fig. 2.

One specimen shall be used.

7.13.2 *Apparatus*

Two alternatives are permitted, but in case of dispute the method of **7.13.2.1** shall be used.

7.13.2.1 A bath of well stirred silicone or equivalent fluid kept throughout the test at 260 $^{+5}_{-0}$ °C. The temperature shall be measured at 25 ± 2.5 mm below the surface.

7.13.2.2 A fluidized sand bath of suitable design kept at a temperature of 260 ± 5°C measured approximately in the same location that will be occupied by the specimen.

7.13.3 *Procedure*

7.13.3.1 *Procedure for use with silicone bath*

The specimen shall be held in a horizontal position at a depth of 25 ± 2.5 mm in a holder of heat capacity low enough to avoid the flint temperature falling below 260 °C. The specimen shall be totally immersed in the fluid for the time given in the relevant specification and immediately after removal shall be inspected for blistering of the foil and delamination of the base material.

7.13.3.2 *Procedure for use with fluidized sand bath*

The specimen shall be immersed edgewise that is with its surface at right angles to the bath surface, for the time given in the relevant specification and immediately after removal shall be inspected for blistering of the foil and delamination of the base material.

7.13.4 *Report*

The report shall state which of the two methods has been used and whether the specimen has blistered or delaminated. A border of 1 mm around the edge of the specimen is excluded from the requirement.

NOTE – Immersion in a silicone or equivalent fluid or in a fluidized sand bath rather than floating on molten solder is specified in this test because it has been found that if molten solder is used, the result of tests carried out in different laboratories on the difficulty of controlling the temperature at the surface of solder bath which in turn is probably due to the large temperature gradient at surface and difficulty of stirring solder effectively.

7.14 Peel Strength

7.14.0 *General*

This test measures the resistance of a 3 mm wide printed conductor to peeling under specified conditions. It is performed either on the test specimen as prepared (as received) or after one of the series of treatments described in **7.14.4** to **7.14.9**. The result after treatment may be expressed as the actual value obtained, or as the percentage retention of a value obtained before the treatment.

7.14.1 *Test Specimen*

The test specimen shall be prepared from a sample of the metal-clad base material under test, and before it is etched its thickness shall normally be that of the material. However, in the case of materials clad with copper foil of nominal mass less than 305 g/m^2 the foil mass may be increased to not more than 335 g/m^2 by any procedure in which ductile copper is deposited. The specimen shall be 50 ± 1 mm wide, and at least 75 mm long, and it shall be printed by the appropriate method of **5.2.5** with the test pattern of Fig. 10.

The number of specimens used for each test shall be sufficient for the peeling of at least 25 mm from each of four strips of foil.

7.14.2 *Measurement of Peel Strength*

The following procedure shall be carried out after the test specimen has been prepared as described in **7.14.1** for peel strength as received or, if required after conditioning as per details of any of **7.10.4** to **7.10.9**.

One end of the strip of the metal foil shall be detached from the base material for a distance of at least 10 mm, and sufficient for the apparatus used. The detached end of the foil shall be gripped over its entire width, for example, with a clamp, and steadily increasing pull shall be applied in a direction 90 ± 5° to the plane of the base material until the metal foil is peeled off at a rate of 50 ± 5 mm/min, the force to do this being measured. A length of at least 25 mm shall be peeled at this rate from each of four strips.

Should copper foils of nominal mass less than 305 g/m^2 break during the test or fail to meet the requirements of the relevant specification, a further set of 4 strips shall be tested from material to which additional copper has been added to a total mass not more than 335 g/m^2.

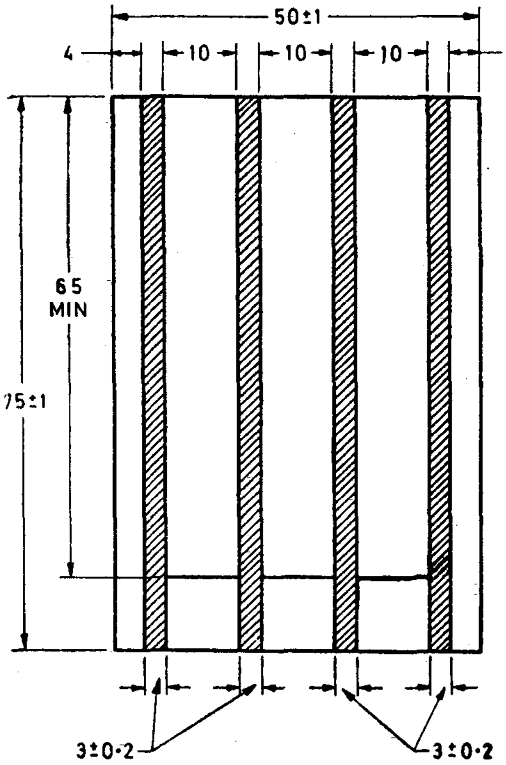


FIG. 10 SPECIMEN FOR PEEL STRENGTH MEASUREMENT

The minimum load per unit width required to peel the foil during the test shall be taken as the peel strength. It shall be expressed in N/mm.

The retention of peel strength of a sample is the peel strength measured after one of the treatments described in **7.14.4** to **7.14.9**, expressed as a percentage of the peel strength, measured on a specimen prepared from the same sample of material.

NOTE – Any apparatus fulfilling the requirements above may be used, but in practice only motor-driven devices for exerting the pull can achieve the required consistency of peeling rate. The pull is usually applied via a measuring device which extends in proportion to the pull exorted upon it, and any local variations in peel strenth therefore produce corresponding variations in the rate of peeling and in accuracies in the observed values while the rate is changing. Only those instruments with an extension rate than 1 mm/N of applied force are normally capable of maintaining the required consistency of peel rate, and of responding sufficiently to local variations in peel strength as the strip is peeled.

7.14.3 *Test Report*

The test report shall state the following :

a) that the test has been carried out either 'as received' or after one of the treatments specified in **7.14.4** to **7.14.9**.

b) if one of the treatments of **7.14.4** to **7.14.9** has been carried out, the relevant conditions and choices of test method;

c) any required observations, for example, of blistering, delamination, detachment of foil from the base material, surface roughness, tackiness or colour change;

d) if the specimen has not blistered or delaminated and the foil has not detached from the base material, the measured peel strength or retention of peel strength, as required by the relevant specification, and defined below; and

e) the additional copper has been added if this is the case.

7.14.4 *Peel Strength After Heat Shock*

If specified for the material under test, the specimen shall be pre-conditioned, allowed to cool to room temperature in a desiccator and subjected to heat shock within 30 minutes of removal from the pre-conditioning atmosphere.

The specimen shall be subjected to heat shock by one of the following three methods (a) or (c), the choice between them to be subjected to agreement between the purchaser and the vendor.

> NOTE – The severity of the heat shock treatments is different, and may, therefore, require the use of different durations of heat shock in the relevant specification.

a) *Liquid bath method* – A bath of well stirred silicone or equivalent fluid, kept at 260 $^{+5}_{-0}$°C shall be used. The temperature shall be measured 25 ± 2.5 mm below the surface.

   The specimen shall be held in a horizontal position , at a depth of 25± 2.5 mm in a holder of heat capacity low enough to avoid the fluid temperature falling below 260 °C. The specimen shall be totally immersed in the fluid for the time given in the relevant specification.

b) *Fluidized sand bath method (Alternative)* – A fluidized sand bath of suitable design kept at a temperature of 260 $^{+5}_{-0}$ °C shall be used.

   The specimen shall be immersed edgewise, that is, with its surface at right angles to the bath surface, for the time given in the relevant specification. The temperature shall be measured approximately in the same location that will be occupied by the specimen.

c) *Solder float method* (*Alternative*) – A suitable solder bath of depth not less than 40 mm shall be used. If circular, the bath shall be not less than 120 mm in diameter, and if rectangular, not smaller than 100 mm x 75 mm. It shall be protected from draughts.

   The temperature of the solder shall be kept at 260 ± 5 °C throughout the test. The temperature shall be measured at a depth of 25 ± 2.5 mm below the surface.

   The conductive pattern on the specimen shall be prepared by a treatment which prevents the adhesion of solder to the metal and has a negligible effect on heat transfer.

   The specimen shall then be dropped, etched side downwards, on to the surface of the clean molten solder for the time given in the relevant specification.

After removal from whichever source of heat shock has been used, the specimen shall be examined for blisters or delamination. If it has not blistered or delaminated, it shall be allowed to cool to between 15 and 35 °C and then used for the measurement of peel strength as described in **7.14.2**.

7.14.5 *Peel Strength After Dry Heat*

The test specimen shall be subjected to dry heat in accordance with IS 9000 (Part 3) : 1977; except that it shall remain in the chamber for 1 hour (for 500 hours if called for). The temperature of the air in the heating chamber shall be that given in the relevant specification. The air in the chamber shall circulate during the whole heating period and the large surfaces of the specimen shall be parallel with the air flow.

Immediately after recovery, the specimen shall be examined for blisters or delamination. If it has not blistered or delaminated, it shall then be used for the measurement of peel strength as described in **7.14.2.**

7.14.6 *Peel Strength After Exposure to Solvent Vapour*

The test specimen, shall be suspended for 120 ± 5 seconds in the vapour of trichloroethane boiling at atmospheric pressure. It shall be examined for blisters or delamination immediately afterwards and again 24 hours later. If it has not blistered or delaminated it shall be used for the determination of peel strength described in **7.14.2.** By agreement between the purchaser and the vendor the test may be carried out with other solvent vapours.

7.14.7 *Peel Strength After Simulated Plating*

This test is intended to measure the resistance of metal-clad base materials to chemical attack, in conditions simulating those of plating.

Method A – Electrolytic Process – The test specimen, shall be made the cathode of an electrolytic cell of which the anode is a carbon rod and the electrolyte is a well stirred aqueous solution of sodium sulphate whose concentration is 10 g anhydrous sodium sulphate (Na_2SO_4) per dm^3 of distilled water, and whose temperature is maintained at 70 ± 2 °C.

The specimen shall be held with the strips of its test pattern vertical so that they are just entirely submerged. They shall be connected electrically by any suitable measns and a dc voltage of about 5 V shall be applied to the cell and adjusted so that the current has a steady value equivalent to approximately 215 A/m^2 of the submerged foil. At the end of 20 ± 1 min, the test specimen shall be removed from the solution, wiped to remove surface moisture and left for about half hour to cool to room temperature.

The specimen shall be examined for non-adherence of the foil. If the foil has not become detached, it shall be used for the measurement of peel strength as described in **7.14.2.**

> NOTE – The test may conveniently be carried out using 500 cm^2 of solution in a 600 cm^2 wide necked flash, and a glass stirrer. A variable resistance of about 30 Ω capable of taking 0.2 A, and an ammeter to measure 0.2 A, will control and measure the current required.

Method B – Electroless Process – The specimen shall be first degreased in hot trichloroethylene vapours. The degreased specimen shall be dipped for 5 minutes in 30 g/l sodium hydroxide and 30 g/l sodium carbonate solution at 93 °C. Then rinse in hot water and dip for 20 minutes in 50 g/l sodium cyanide solution at 23 ± 5 °C . Again rinse in hot water and dip the specimen for 30 minutes in 10 g/l sulphuric acid (specific gravity 1.836) and 30 g/l boric acid solution. Finally rinse the specimen in hot water and dry for one hour at 93 to 99 °C. The specimen shall be examined for non-adherence of the foil. If the foil has not become detached, it shall be used for the measurement of peel strength as described in **7.14.2**.

7.14.8 *Peel Strength at High Temperature*

A bath of well-stirred sillicone or equivalent liquid, kept within 2 °C of the temperature given in the relevant specification , shall be used. The temperature shall be measured 25 ± 2.5 mm below the surface. The metal foil on the test specimen, shall be detached from one end of the base material for a distance of at least 25 mm, and sufficient for the apparatus used. The detached end of the foil shall be gripped over its entire width as described in **7.14.2** before immersion in the hot fluid. The specimen shall be held in a horizontal position in the fluid, at a depth of 25 ± 2.5 mm, in a holder of heat capacity low enough to avoid the temperature in the fluid from falling below the range specified.

The pull as described in **7.14.2** shall be applied after the specimen has reached the test temperature. The test shall be completed within 3 minutes of immersion in the fluid, and the specimen shall be kept immersed for the whole time of testing.

For the testing of peel strength at temperatures below 160 °C, the test may alternatively be carried out in a circulating-air oven maintained within 2 °C of the temperature given in the relevant specification. In this case the test shall be carried out as described in **7.14.2** after the specimen has reached the required temperature, and shall be completed within 75 minutes after the specimen and apparatus have been introduced into the oven.

7.14.9 *Peel Strength After Temperature Cycling*

The test specimen shall be subjected to temperature cycling. The duration and temperatures shall be as specified in the detail specification. Immediately after recovery, the specimen shall be examined for blisters or delamination. If it has not blistered or delaminated, it shall then be used for the measurement of peel strength as described in **7.14.2**.

7.15 Pull off Strength

7.15.1 *Test Specimen*

The test specimen shall be a piece of sheet under test, of any convenient size and printed by the appropriate method of **5.2.5** with a test pattern consisting of 10 or more lands of diameter 4± 0.1 mm with a spacing not less than 20 mm. It is convenient for each land to have central etched hole of diameter about 0.6 mm for locating the drill.

A hole of diameter 1.3 ± 0.1 mm shall be drilled through the centre of each land.

7.15.2 *Soldering Tool*

The soldering iron shall have a copper bit 30 ± 5 mm long, and 5 ± 1 mm diameter, with its end forming an angle of 45 ± 10 °C.

The temperature of the bit shall be 260 ± 5 °C throughout the test.

7.15.3 *Solder*

The solder shall be a 60/40 tin/lead alloy with a non-corrosive resin core complying with IS 1921 : 1975 and in the form of wire of diameter not greater than 1.5 mm.

7.15.4 *Procedure*

Ten lands shall be tested.

The lands shall be evenly tinned for 4 ± 1 second with soldering iron and a minimum amount of solder.

A piece of wire of 0.9 to 1.0 mm diameter previously tinned with solder shall be soldered at right angles to the test specimen, to the centre of the land. The wire shall be attached to the foil in such a position that it passes through the foil into a drill hole. The fillet form between the wire and the land shall cover the entire area of the land. The time taken for this soldering process shall be 4 ± 1 s. During this soldering and subsequent cooling, the wire shall not be removed. To ensure this the wire and the test specimen may be held in a jig. The test specimen shall be cooled at least for 30 minutes before testing.

By means of a tensile testing machine a load shall be applied pulling the wire at right angles to the test specimen and increase steadily at 5 to 50 N/s, until the land separates from the base material, or the wire breaks.

The pull in N required to detach the land or break the wire shall be noted. Breaking of the lead at or below the specified value or lead pull out shall not be considered as a failure, but the test shall be repeated. In no case shall the lead be resoldered and pulled again.

7.16 Mould Growth

7.16.1 *Test Specimen*

The test specimen shall be a 50 mm square piece of metal-clad base material cut from the sheet under test.

Four specimen shall be tested.

7.16.2 *Test Procedure*

The test shall be carried out as described in IS 9000 (Part 10) : 1979.

7.16.3 *Report*

The mould growth and any other change in the laminate shall be reported.

8 NON-ELECTRICAL TESTS ON BASE MATERIAL

8.1 Flexural Strength

8.1.1 *Test Specimen*

The test specimen shall be prepared from a sample of the metal-clad base material under test, from which the metal has been completely removed by the appropriate method (according to **5.2.5**). Its thickness shall be that of material, including any bonding medium which may be present. Its length shall not be less than 20 times its thickness, and its width shall be as given in Table 6.

Table 6 Dimensions of Test Specimen

(*Clause* 8.1.1)

Height, *h* (1) mm	**Breadth**, *b* (2) mm
Over 1 Up to and including 3	5 ± 0.5
Over 3 Up to and including 10	10 ± 0.5
Over 10 Up to and including 20	20 ± 0.5
Over 20 Up to and including 35	35 ± 0.5
Over 35 Up to and including 50	50 ± 0.5

Ten specimens shall be tested. Five shall have the longest axis parallel to the length of the sheet and five shall be parallel to its width.

8.1.2 *Procedure*

The test specimen shall be placed on two supports as shown in Fig. 11. The ratio of distance L to thickness of the laminate shall be 16 : 1. The radius r_1 shall be 5 ± 0.1 mm whereas r_2 shall be 0.5 ± 0.2 mm for thickness up to and including 3 mm and 2 ± 0.2 mm for more than 3 mm thick laminates. It shall be loaded at mid-span without impact. The relative rate of movement of loading mandrel and support shall be half of the thickness of material per minute ($V - n/2$ mm/min). The flexural stress at rupture shall be calculated for each specimen by following formulae:

$$\text{Flexural stress} = \frac{3\,FL}{2\,bh^2}$$

where

F is applied load in newton,

L is span length in cm,

b is width of specimen in cm, and

h is thickness of specimen in cm.

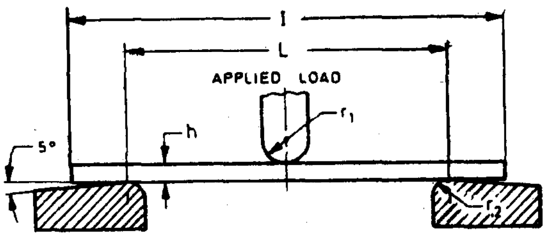


FIG. 11 POSITION OF TEST PIECE DURING TEST

8.1.3 *Report*

The report shall state the average flexural strength at rupture, expressed as N/cm^2, average of the 5 lowest values shall be taken.

8.2 Flammability

8.2.0 *General*

The tests which follow are laboratory tests for quality control use using low energy sources of ignition. The results from the different tests do not necessarily rank different materials in the same order, and none of the results attempts to predict the behaviour of materials in any large scale fire.

Materials of different thickness should not be expected to give smaller results when tested by these methods.

8.2.1 *Ignition Source*

The ignition source shall be a blue flame produced from a Bunsen burner having a tube length of approximately 1.0 mm and an inside diameter of 0.5 ± 0.5 mm. The tube shall not be with any end attachment, such as stabilizer.

A supply of technical grade methane gas with a suitable regulator and meter to produce a uniform gas flow shall be used.

The required flame shall be obtained by adjusting the gas supply and the air ports of the burner until a yellow-tipped blue flame of the height specified in the relevant test is produced, and then by increasing the air supply until the yellow tip just disappears. The height of the flame shall be measured again and corrected, if necessary.

8.2.2 *Horizontal Burning Test for Rigid Materials*

8.2.2.1 *Scope*

The purpose of this test is to determine the flammability of rigid sheet materials which have a limited resistance to ignition and to the spread of small fires caused by the accidental overheating of a single electronic components. The test is carried out using a small test flame whose intensity is of a similar order to that of the actual hazard. The test result is expressed in terms of the burning time of the specimen after exposure to the test flame.

8.2.2.2 *Test chamber*

The test shall be conducted in a room or enclosures protected from air currents, but provided with means of venting the fumes from burning specimens. A hood may be used, but its exhaust fan shall be turned off during the tests and allowed to operate only to clear the fumes between tests.

8.2.2.3 *Test specimens*

The test specimens shall be prepared from a sample of the metal-clad base material under test from which the metal has been completely removed by the appropriate method described in **5.2.5**. It shall be 125 ± 5 mm long, 13 ± 1 mm wide and before etching its thickness shall be that of the material. Its edges shall be smooth, the radius of its corners shall not exceed 1.3 mm and it shall be marked by scribing it with a line perpendicular to its longitudinal axis, 25 ± 0.5 mm away from the end which is to be ignited.

Four specimens shall be used.

8.2.2.4 *Conditioning*

Before testing, the specimens shall be kept for 48 hours in the conditions defined in **5.2.1** unless otherwise specified.

8.2.2.5 *Procedure*

The specimen shall be clamped in a rigid support at the end further from the scribed line so that its longitudinal axis is horizontal, its transverse axis is inclined at 45 ± 10° to the horizontal, and the line on the specimen may be seen. A piece of clean wire gauze with approximactely 8 meshes per cm and approximately 100 mm square shall be clamped in a horizontal position 10 ± 1 mm below the specimen with 13 ± 1 mm of the unsupported end of the specimen projected beyond the edge of the gauze as shown in Fig. 12.

A blue flame 25 ± 1 mm high, as specified in **8.2.1** shall be applied so that the free end of the specimen, to a length of approximately 6.5 mm is subjected to the flame. The centre axis of the burner shall be in the same vertical plane as the lower horizontal edge of the specimen and at an angle of 45 ± 10° to the horizontal and its position shall not be changed while the flame is applied.

The flame shall be applied to the specimen for 30 seconds and then removed. The burning time in seconds shall be measured from the instant of removal of the burner flame to that when the flame from the specimen goes out. Observations shall be made as to whether burning proceeds past the scribed line.

8.2.2.6 *Report*

The report shall state:

a) Average of the four burning times;

b) Whether the burning of any of the specimens proceeds past the scribed line;

c) Whether the material melts or drips, and if it drips, burns; and

d) Thickness of the sheet under test.

8.2.3 *Vertical Burning Test for Rigid Materials*

8.2.3.1 *Scope*

The purpose of this test is to determine the flammability of rigid sheet materials which have a greater resistance to ignition and to the spread of small fires caused by the accidental overheating of single electronic components, than materials evaluated by the horizontal burning test of **8.2.2.** The test is carried out using a small test flame whose intensity is of a similar order to that of the actual hazard. The test result is expressed in terms of the burning time of the specimen after exposure to the test flame.

8.2.3.2 *Test chamber*

The test chamber shall be as described in **8.2.2.2.**

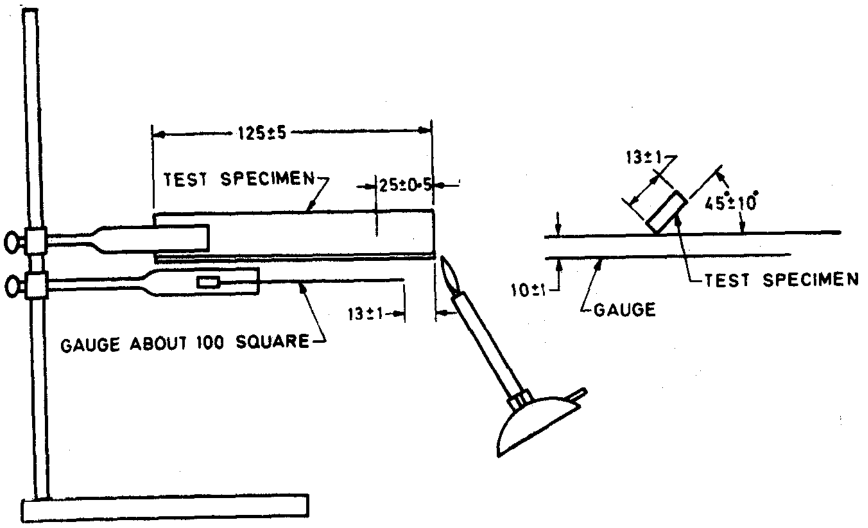
8.2.3.3 *Test specimens*

The test specimen shall be as specified in **8.2.2.3** except that it shall not be scribed with a line.

The number of specimens shall be 10 or any greater number required to complete the test procedure (*see* **8.2.2.5**).

8.2.3.4 *Conditioning*

One set of five specimens shall be kept for 48 hours in the conditions defined in **5.2.1** prior to testing.



All dimensions in millimetres.

FIG. 12 FLAMMABILITY TEST

The other set of five specimens shall be heated in a circulating- air oven for 24 hours at 125 ± 2 °C unless otherwise stated then cooled in a desiccator for 4 hours at room temperature prior to testing.

8.2.3.5 *Procedure*

The specimen shall be supported with its longitudinal axis vertical, by clamping it within 6 mm of the top by a clamp on a stand, so that the lower end of the specimen is 10 ± 1 mm above the top of the burner tube and approximately 300 mm above a wooden board which is covered with a single layer of tissue paper.

The burner, remote from the specimen, shall be adjusted as described in **8.2.2** to give a blue flame 19 ± 1 mm high, then placed centrally under the lower end of the specimen and allowed to remain for 10 seconds.

It shall then be moved at least 150 mm away and the burning time in seconds shall be measured from the instant of removal of the burner flame to that when the flame from the specimen goes out. When the specimen ceases to flame, the burner shall immediately be replaced in its original position under the specimen. After 10 seconds the test flame shall again be withdrawn and the duration of flaming shall be noted. If the test flame is extinguished during either application, it shall be re-ignited immediately and reapplied so that the total tune of application is still 10 seconds. There shall be no more than three applications of the test flame during any 10 seconds ignition period otherwise the material may not be evaluated by this test.

If the specimen drips molten or flaming material during either flame specification, the burner may be tilted to an angle up to 45° and also slightly withdrawn away from one of the 13 mm sides of the specimen during the flame application, to avoid material dripping into the tube of the burner. If the specimen drips molten of flaming material or is consumed during the test, the burner shall be hand-held and the 10 mm distance between the bottom of the specimen and the top of the burner tube shall be maintained during the flame application. Any molten strings to the material shall be ignored, and the flame shall be applied to the major portion of the specimen.

If the total of the 10 burning times meets the requirements in the relevant specification but individual burning times exceed the relevant requirements a further set of five specimens shall be tested. If all the requirements are met by the second set, they shall be deemed to be satisfied.

If the total of the 10 burning times for any set of 5 specimens exceeds the requirements in the relevant specification by no more than five seconds, a further set of five specimens shall be tested and if the requirements for total burning time are met, they shall be deemed satisfied.

8.2.3.6 *Report*

The report shall state the thickness of the sample, and for each of the specimens:

a) Duration of flaming after the first removal of the test flame;

b) Duration of flaming after the second removal of the test flame;

c) Whether or not the specimen burns up to the holding clamp;

d) Whether or not the specimen drips flaming particles which ignite the tissue paper; and

e) Any variation of procedure allowed in **8.2.3.5**.

8.2.4 *Vertical Burning Test for Flexible Materials*

8.2.4.1 *Scope*

The purpose of this test is to evaluate the flammability and to determine the burning rate of thin sheet or film in thickness between 0.05 and 0.4 mm when exposed to a small test flame. The test is carried out using a small test flame whose intensity is of a similar order to that of a fire being started by the accidental overheating of a single electronic component. The test result is expressed in terms of the extent to which the specimen is consumed during the test and in terms of its burning rate.

8.2.4.2 *Test specimens*

Four specimens shall be tested.

The specimens shall be prepared from a sample of the metal-clad base material from which the metal has been completely removed by the appropriate method of **5.2.5**. The specimens shall not be taken from within 25 mm of the edge of the sheet or roll.

The ends of the gargelines shall be defined by small nicks cut into the edges of the strips.

8.2.4.3 *Conditioning*

Before testing, the specimens shall be kept for 48 hours in the conditions defined in **5.2.1** unless otherwise specified.

8.2.4.4 *Procedure*

The test shall be carried out with the specimens clamped as shown in Fig. 13 and with a weight of about 5 g suspended from its lower end if necessary to avoid curling.

8.2.4.5 *Report*

The test report shall state:

a) The average thickness of the test specimens;

b) The burning behaviour of the specimens, described in one of the following ways :

    1. Material does not ignite after 15 seconds of application of flame;
    2. Ignition is apparently prevented by shrinkage of the specimen, in which case the test is reported as not applicable because of shrinkage;
    3. Material ignites but the flame extinguishes before reaching the lower gauge mark, in which case apparent cause of extinction is reported;
    4. Material ignites but the flame extinguishes before reaching the upper gauge mark, in

which case the apparent cause of extinction and the average burning rate in mm/s are reported; and

5. Material burns, melts off or chars up to the upper gauge mark, in which case the average burning rate in mm/s is reported.

8.3 Water Absorption

8.3.1 *Test Specimen*

The specimens shall be prepared from a piece or pieces of the metal-clad base material under test from which the metal foils have been completely removed by the appropriate method in accordance with **5.2.5.** Specimen shall be square of size 50 ± 1 mm and thickness shall be that of base material. The specimen shall be dried in an oven for one hour at specified temperature before testing.

8.3.2 *Procedure*

The test shall be considered out as specified in IS 1998 : 1962.

8.3.3 *Report*

The value of water absorption shall be reported in mgms per test piece or percentage absorption. It shall be within the values specified in the relevant specification.

8.4 Coefficient of Linear Thermal Expansion

To determine the coefficient of linear thermal expansion (CTE) of base materials by thermomechanical analysis (TMA).

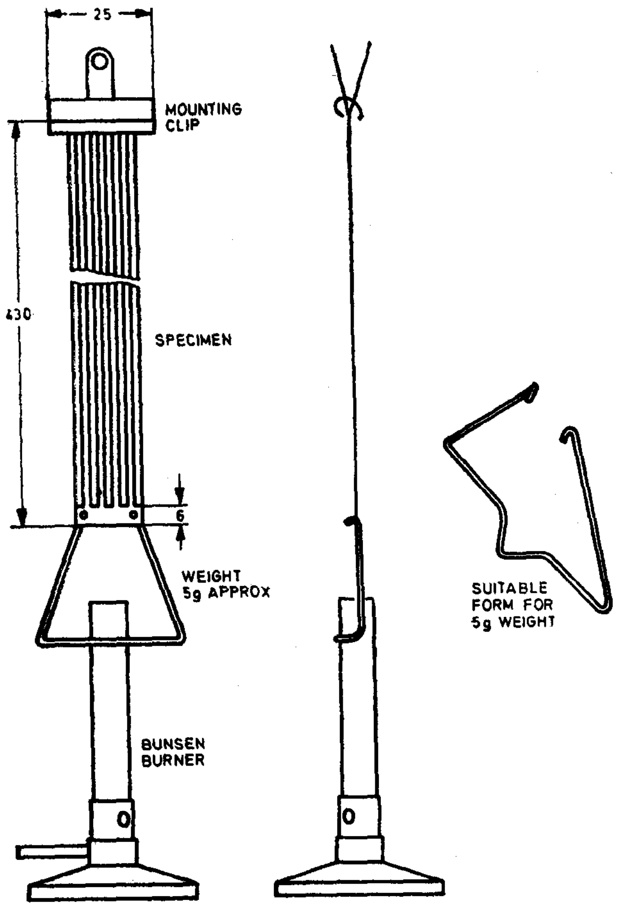
8.4.1 *General*

The TMA method shall be applied to materials that exhibit sufficient rigidity over the temperature range being used to ensure that no significant indentation by the sensing probe occurs.

The technique involves the measurement of the change of length of a material under non-oscillating load as a function of temperature whilst that material is subjected to a controlled temperature programme.

8.4.2 *Test Specimen*

The test specimen shall be prepared from a sample of the metal-clad base material under test from which the metal has been completely removed by the appropriate method of **5.2.5.** The specimen shall be small enough



All dimensions in millimetres.

FIG. 13 ARRANGEMENT FOR VERTICAL BURNING TEST FOR FLEXIBLE MATERIALS

to fit on the base of the specimen holder but also large enough for the proble to make good contact. The specimen shall be flat and parallel sided in the direction of measurement.

A minimum of three specimens shall be used.

8.4.3 *Apparatus*

The apparatus shall consist of the following:

- A specimen holder into which the specimen may be placed. This should be able to withstand repeated temperature cycles within the range $-150\ ^\circ C$ to $+ 600\ ^\circ C$ (or as appropriate for the particular material under test).
- A suitable specimen probe. The shape and dimensions of the probe tip will vary with the material under investigation.
- A means of sensing movement of the specimen probe.
- A means of applying heat in a uniform manner to the specimen. The application of heat shall be controlled so that particular rates of heat can be applied to the specimen.
- A means of determining the temperature of the specimen with accuracy.
- A thermocouple with relevant compensation has been found suitable.
- An apparatus for recording the measurements taken.

8.4.4 *Procedure*

The test specimen shall be placed into the holder and the probe brought into contact with the test specimen which is normal to the direction of measurement. After ensuring that the probe is in contact with the test specimen, a mass of 2 g is added to ensure that contact is maintained throughout the determination. Other loads may be used but they should be entered in the report.

The test specimen shall be heated at a rate to result in a temperature change of approximately 2 °C per minute over the relevant temperature range. Other heating rates may be used; however, they shall be entered in the report.

The coefficient of linear thermal expansion shall be determined from the linear portion of the temperature versus movement characteristic over the temperature range of interest using the formula:

$$a = \frac{L_2 - L_1}{T_2 - T_1} \; \frac{1}{L}$$

where

a = coefficient of linear thermal expansion,

L_1 = initial length in mm,

L_2 = final length in mm,

T_1 = initial temperature in K, and

T_2 = final temperature in K.

NOTE – For particular systems data have to be corrected by appropriate formula, for example.:

$$a = \frac{L_2 - L_1}{T_2 - T_1} \cdot \frac{CS}{L_1}$$

where

C = constant for the apparatus, and

S = signal sensitivity.

If measurement in other atmospheres is desired, a purge gas can be used.

8.4.5 *Report*

The report shall state:

1. Method of test specimen preparation;
2. Dimensions of specimen;
3. Specimen orientation with respect to the original base material and /or the direction of the orientated fibre fillers;
4. Specimen orientation in the holder;
5. Heating rate;
6. Load used on the probe;
7. Gas and gas flow rate (optional);
8. Temperature range of measurement; and
9. Coefficient of linear thermal expansion.

8.5 Measling

To determine an internal condition occurring in the base material in which the glass fibres are separated from the resin at the weave intersection.

NOTE – This condition manifests itself in the form of discrete white spots or crosses below the surface of the base material, and is usually related to thermally induced stress.

8.5.1 *General*

This test shall only be applied to specimens 0.8 mm or greater in thickness.

8.5.2 *Test Specimen*

The test specimen shall be prepared from a sample of the metal-clad base material under test from which the metal has been completely removed by the appropriate method of **5.2.5**. It shall be 75 mm long, 50 mm wide, and before etching its thickness shall be that of the base material. Its edges shall be sanded smooth and care should be taken to avoid fracturing of the resin.

Four specimens are to be prepared, one of which is retained as a control and three shall be used for testing.

8.5.3 *Procedure*

Sufficient water is placed in a pressure cooker to allow for some evaporation during the whole test. A depth of 2 cm to 3 cm is usually suitable. The specimens are mounted vertically in a rack and are placed in the pressure cooker at least 5 mm above the water level. The cooker is then heated up to the boiling point of the water on a hot plate. The lid of the cooker is located in position and heating continued until steam escapes through the pressure orifice. At this point the pressure weight is located in the orifice and the pressure shall rise to an absolute pressure of 2 bar (over pressure = 1 bar, gauge pressure = 14.7 psi) ± 0.2 bar (temperature approximately 120 °C) within 15 min. It is then held for 25 mm at 2 bar. The pressure cooker is then rapidly cooled under cold running water and the specimens are removed and blotted dry. The specimens are allowed to stand for 1 h at room temperature and then edge-dipped vertically with their long edge parallel to the surface of the solder into a hot solder bath [as described in the first three paragraphs of **6.15.4** (c)] for 15 s to one half of their width. The specimens are then removed and after removal of adherent solder, examined for blistering, measling and delamination.

A border of 1 cm shall be excluded from the requirement.

8.5.4 *Report*

The report shall state whether the specimen shows blistering, measling and/or delamination.

8.6 Glass Transition Temperation

8.6.1 *DSC Method*

8.6.1.1 *Object*

To determine the glass transition temperature (Tg) of base materials by the Differential Scanning Calorimetry (DSC) method.

8.6.1.2 *General*

The DSC method is used to assess changes in the heat capacity of base materials by measuring the difference of energy input into a sample and a reference, while both are subjected to a controlled temperature programme.

8.6.1.3 *Test specimens*

Test specimens shall be prepared from a sample of the metal-clad base material under test from which the metal has been completely removed by the appropriate method of **5.2.5**. Test specimens shall be of suitable size and shape for the sample holder and measuring system and weigh 10 to 30 mg.

NOTE – Any known thermal history of the sample shall be stated in the report.

A minimum of three specimens shall be used.

8.6.1.4 *Apparatus*

The apparatus shall consist of the following:

a) A chamber into which the test specimen and an inert reference can be placed such that they will both be subjected to the same enviromental stimulated viz, temperature and atmosphere. The reference can be an empty crucible.
b) A suitable method of introducing and venting an inertgas such that the chamber can be filled while maintaining a steady flow rate of gas over the test specimen and reference without causing turbulance (optional).
c) Measuring apparatus to measure the energy inputs to the test specimen and reference to the required sensitivity.
d) Controlling equipment to control the temperature of the chamber such that a uniform heating rate of 20 °C ± 2 °C per minute can be achieved throughout its internal volume. Other temperature rates can be used, if applicable.
e) Sample crucibles made of aluminium or other suitable material. The crucibles must be so designed that the requirement of (a) above can be performed.
f) A reference of suitable thermal capacity for example, an empty crucible.
g) A supply of inert gas for example, oxygen-free nitrogen.
h) Apparatus for recording and displaying the temperature and energy flow (a thermogram).

8.6.1.5 *Procedure*

The test specimen and the reference shall be placed in the crucible and capped.

The capped crucibles shall then be placed in their required positions in the chamber and the heating of the test specimen and reference started with a rate of 20 °C ± 2 °C per minute.

Along with the heating an inert gas flow can be applied (optional). The test specimens and reference shall be heated from 30 °C ± 2 °C to a temperature which is at least 30 °C ± 2°C higher than the minimum glass transition temperature stated in the relevant specification.

The glass transition temperature shall be determined from the thermogram (*see* Fig. 14) produced by extrapolating the slopes of the curve before and after the transition point endotherm and constructing the tangent in the point of inflection. The temperature halfway between the points of intersection of the tangent with the extrapolation lines in the glass transition temperature. The obtained value shall be the lowest measured from at least three determinations.

8.6.1.6 *Report*

The report shall state:

1. the method of test specimen preparation;
2. the weight of the test specimen;
3. the reference (whether empty crucible etc) and weight;
4. any heat treatment other than that covered in (a) above;
5. the heating rate if other than 20 °C per minute; and
6. the glass transition temperature.

8.6.2 *TMA Method*

8.6.2.1 *Object*

To determine the glass transition temperature (Tg) of base materials by Thermomechanical Analysis (TMA).

8.6.2.2 *General*

The TMA method is used to assess changes in the dimensions of base materials while the materials are subjected to a controlled temperature programme.

8.6.2.3 *Test specimen*

Test specimens shall be prepared from a sample of the metal-clad base material under test from which the metal has been completely removed by the appropriate

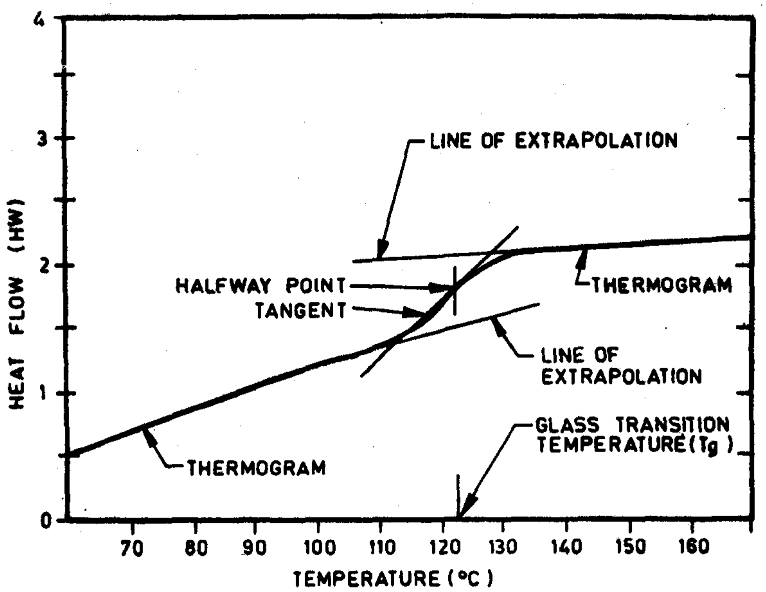


FIG. 14 GLASS TRANSITION TEMPERATURE THERMOGRAM

method of **5.2.5**. Test specimens shall be of suitable size and shape for the sample holder and measuring system and weigh 7.5 to 10 mg. They shall be flat and parallel sided in the direction of measurement and shall be free from burrs and fibres.

A minimum of three specimens shall be used.

8.6.2.4 *Apparatus*

The apparatus shall consist of the following:

a) A specimen holder into which the specimen can be placed,

b) A suitable specimen probe,

c) A means of applying heat in a uniform manner to the specimen, and

d) A measuring device to measure the temperature of the specimen with accuracy.

8.6.2.5 *Procedure*

The specimen shall be placed in the holder and the probe brought into contact with the test specimen surface in line with the direction of measurement. After ensuring that the probe is in direct contact with the test specimen a load of 2 g is added to ensure that contact is maintained throughout the determination.

The test specimen temperature sensor shall be placed, as near to the specimen as possible, without interfering with the operation of the probe. The heating source shall be placed around the test specimen, the probe, the temperature sensor and the holder.

The test specimen shall be heated with a constant rate of 10 ± 2 °C per minute over the relevant temperature range.

The glass transition temperature shall be determined from the thermal expansion diagram (*see* Fig. 15) by extrapolating the slopes of the curve before and after the sharp bend. The temperature at the intersection point of the extrapolation lines is the glass transition temperature. The obtained value shall be the lowest measured from at least three determinations.

8.6.2.6 *Report*

The report shall state:

1. the method of test specimen preparation;
2. the dimensions of the test specimen;
3. the specimen orientation with respect to machine direction of the original base material;
4. the specimen orientation in the holder;
5. the load on the probe;
6. the temperature range;
7. the heating rate; and
8. the glass transition temperature.

8.7 Cure Factor

8.7.1 *Object*

To determine the cure factor of base materials.

8.7.2 *Test Specimens*

Test specimens shall be prepared as described in **8.6.1.3**

A minimum of three samples shall be tested.

8.7.3 *Apparatus*

Apparatus as described in **7.6.1.4** shall be used.

8.7.4 *Procedure*

a) *Process Step 1*

The procedure for measuring glass transition temperature (*see* **8.6.1.5**) of the material shall be followed.

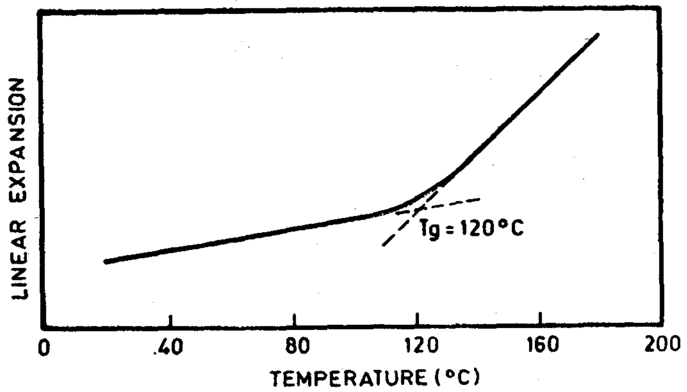


FIG. 15 THERMAL EXPANSION

When the heating is completed the test specimen and reference shall be maintained at 170 $^{+5}_{-0}$ °C for 10 $^{+5}_{-0}$ minutes. After this time the test specimen and reference material shall be cooled to 30 °C immediately and be allowed to stabilise for 10 $^{+5}_{-0}$ minutes without removing then from the chamber.

The glass transition temperature shall be determined as described in **8.6.1.5.**

b) *Process Step 2*

The test specimen and reference shall be resubjected to process step 1.

The glass transition temperature shall be measured again.

The cure factor shall be determined from the following formula :

$$CF = 1 - \frac{(Tg_2 - Tg_1)}{Tg_1}$$

where

CF is the cure factor,

Tg_1 is the glass transition temperature determined by process step 1,

Tg_2 is the glass transition temperature determined by process step 2.

The cure factor determined shall be the lowest value measured from three determinations.

NOTES

1 Consideration must be given to the affects of water absorption of the test specimen when determining cure factor by means of measuring glass transition temperature.

2 Prolonged exposure to elevated temperature can thermally degrade the resin structure and lead to incorrect cure factors of greater than 1.0.

8.7.5 *Report*

The Report shall state:

a) the method of test specimen preparation;

b) the weight of the test specimen;

c) the reference (whether empty crucible etc) and weight;

d) any heat treatment other than that covered in (a) above;

e) the heating rate, if other than 20 °C per minute; and

f) the cure factor.

ANNEX A

(*Clause* 2.1)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
1885 (Part 6) : 1978	Electrotechnical vocabulary: Part 6 Printed circuits (*first revision*)
1921 : 1975	Resin-cored solder wire (*first revision*)
1998 : 1962	Methods of test for thermosetting synthetic resin bonded laminated sheets
3396 : 1979	Methods of test for volume and surface resistivities of solid electrical insulating materials (*first revision*)
4486 : 1967	Recommended methods for the determination of the permitivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths
8516 : 1977	Methods of test for determining electrolytic corrosion with insulating materials
9000 (Part 1) : 1988	Basic enviromental testing procedures for electronic and electrical items : Part 1 General (*first revision*)
9000 (Part 3) : 1977	Basic environmental testing procedures for electronic and electrical items : Part 3 Dry heat test
9000 (Part 4) : 1979	Basic environmental testing procedures for electronic and electrical items : Part 4 Damp heat (steady state)
9000 (Part 10) :1980	Basic environmental testing procedures for electronic and electrical items : Part 10 Mould growth test
9000 (Part 18) :1981	Basic environmental testing procedures for electronic and electrical items : Part 18 Solderability test

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Printed at New India Printing Press, Khurja, India